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Supplementary material for "Using a Pop-Science Book to Teach Introductory Neuroscience: Advantages for Science Majors and Non-Science Majors Alike"
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NSCI 1001: Fundamental Neuroscience: Understanding Ourselves
Fall 20XX

Course Times: Tu/Th Lectures

Text: *The Brain that Changes Itself*
Norman Doidge, MD
Penguin Books, 2007

Credits: 3

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Course Objectives: In declaring the 1990s "The Decade of the Brain", Congress and then President George H.W. Bush acknowledged what others had known for millennia; the critical importance of the nervous system for who we are as people, and the devastating impact of nervous system disorders. Certainly all of us will be touched personally or through friends and family by nervous system disorders. As such, it is critically important that our broad populace is educated in modern neuroscience to make informed decisions, both personally and socially, relative to this key component of public health. Our principal aim for NSCI 1001 is that University students after finishing this course should be able to objectively assess the large quantity of neuroscience information that is constantly being presented to the public at-large across various media outlets, and explain to their peers and family the potential importance of these discoveries. This aim is accomplished by couching neuroscience principles within real-life case studies of individuals with nervous system disorders. These disorders serve as a basis for didactic exchange about the scientific and technological underpinnings of the therapeutic approaches. These discussions include a critical evaluation of the science, its relation to societal views of mental illness and neurological disorders, and where appropriate ethical considerations.

Course Approach: The course will be composed of two weekly lectures. Because there are no prerequisites and no prior knowledge of the nervous system is assumed, the course will begin with an overview in which students will learn the fundamentals of our nervous system. Following the teaching of the biological essentials, students will learn about the brain through reading and lecture discussions of the book, "The Brain that Changes Itself" written by Dr. Norman Doidge. This is not a standard text, but rather a series of case studies described by a psychiatrist. It is extremely well written and is meant to be approachable to non-experts of the field of neuroscience. By examining in detail ten distinct neurological phenomena, students will gain perspective regarding the complexity of our nervous system. In addition, the case-study approach will serve as the means to delve deeper into the methods and recent discoveries of neuroscientists. By presenting information in a more practical, health-related fashion, we hope to better engage the students during the lectures.

Relation to the Liberal Education Technology and Society Theme: A critical component to this course is the understanding and application of long-standing and emerging technologies (including ethical issues related to the use of some of these technologies) to studies of the

nervous system. The course will provide the basis for each of the technologies and describe how technology has bolstered our view of how the nervous system functions and the diagnosis and therapeutic approaches to nervous system disorders. By emphasizing core concepts of neuroscience and applying them to examples of the human condition, the information in this course will prove valuable throughout each student's life and permit students to understand and critically evaluate new technologies.

Student Learning Outcomes: The goal of this course is to present neuroscience as an integrated, experimental discipline. Factual knowledge is important, but given the course goals, students will be required to integrate these facts to develop concepts and solve problems of nervous system function and dysfunction.

Course Grading: The lecture grade (worth a total of 400 points) will be based on four essay examinations worth 100 points each.

Extra Credit Assignment: For each of the last 20 lectures (after the basic neuroscience lectures), students will have the opportunity at the end of class to write a 1-2 sentence statement of the main point(s) of that day's lecture and an unanswered question on the day's topic. For each assignment completed the student will be credited with 0.25 points. The instructor for the day's lecture will do the same exercise and post the take home message for that lecture so the students can compare their views with those of the instructors. If a student participates in all of these assignments, there is the possibility of 5 additional points towards the final course total.

Grade Scale:	400-372 points = A	319-308 points = C+
	371-360 points = A-	307-292 points = C
	359-348 points = B+	291-280 points = C-
	347-332 points = B	279-268 points = D+
	331-320 points = B-	267-252 points = D

LECTURE SCHEDULE

Lecture 1: Introduction to Neuroscience 1001

Goal: The first class of the semester will detail the overall objectives of the course, our expectations of the students, and will provide a preview of some of the neuroscience topics that will be discussed over the semester. We will emphasize the goal of demystifying the complexities of the nervous system so students will be able to take this information and use it to understand nervous system disorders and make lifelong informed decisions about their individual health care and that of family and friends.

Lecture 2: Introduction to the Brain: Part I

Goal: The guiding concept of the physical structure of the brain is that it is informative of principles of how the nervous system functions. Students will learn about the anatomy of the human nervous system. This will include an understanding of basic cell structure (neuron vs. glia), how groups of cells form brain nuclei, how neurons from one brain nucleus project to other regions of the nervous system, how sensory information is relayed into the nervous system and

how the central nervous system projects to the peripheral nervous system for motor output. The technologies used to identify nervous system structure will be integrated with the anatomical presentation to provide the experimental base for neuroanatomy and to help students recognize nervous system structure using modern human imaging approaches (e.g., MRI and histological images). The emphasis will be on the anatomical structures that form the basis for the different disorders presented in the text, so that this information will be repeated and integrated with the lecture materials throughout the semester.

Relationship to Technology and Its Impact on Society: In this lecture both classic and modern technologies used to uncover the organization of the nervous system are discussed. Satellite images are used as metaphors for these neuroanatomical methods with views of our community from the global level down to individual houses. The views of the organization of the brain are compared between in vitro and in vivo imaging techniques. Further, the common features of the nervous system viewed across mammalian species are emphasized. This concept is crucially important to understand how animals can be used to effectively model the structure of the human nervous system.

Lectures 3 and 4: Introduction to the Brain: Parts II and III

Goal: Because the nervous system is essentially an organ of communication throughout the body, this section will develop the language of that communication. During the second week of class, students will learn about basic nervous system physiology, focusing on the neuronal electrical potential underlying the action potential (relaying information from one region of the cell to another) and neurotransmitter release (relaying information from one cell to another). In addition, different classes of neurotransmitters will be described, having potential for both excitatory as well as inhibitory effects on nerve cells. The electrical and chemical languages of the nervous system then will be integrated in the semester's lectures highlighting the basis for diseases of the nervous system and where appropriate the basis for therapeutic drug treatments.

Relationship to Technology and Its Impact on Society: In this lecture we provide several examples by which, simply understanding the fundamentals of electrical signaling, major strides are being made to cure paralysis, Parkinson's disease, epilepsy and many other nervous system disorders. One example is the use of deep brain stimulation in which electrodes are inserted directly into the brain to affect electrical signaling in a way that can treat diseases such as Parkinson's. A second example is where electrodes are used to record the normal activity of the motor cortex of a monkey, and these electrical signals are read by a computer. The computer then simulates these signals in a way that it can control the movement of a robot. This technology has the potential to permit people to use their brains to control prosthetic limbs.

Lectures 5 and 6: A Woman Perpetually Falling (Vestibular System), Doidge Chapter 1

Goal: Chapter 1 of *The Brain that Changes Itself* describes an individual who was administered large quantities of a common antibiotic resulting in the death of the hair cells in her vestibular system. The neurological deficit (a complete loss of the body's position in space when visual information is absent (e.g. eyes closed) was thought to be permanent and incurable. Yet, through use of electrical inputs onto the tongue, vestibular information can be provided by a simple device and interpreted by the brain to overcome the neurological deficit. Students will gain an understanding of the vestibular system in particular, and perception and sensation in

general. In addition, this case-study will be used as a launching point to describe various brain-machine interface models and their potential therapeutic roles in various neurological deficits.

Relationship to Technology and Its impact on Society: Students will gain an understanding of the vestibular system, perception and sensation. A case-study will be used as a launching point to describe various brain-machine interface models and their potential therapeutic roles in various neurological deficits. One example is a brain-machine interface used to provide vestibular information to the brain via electrical stimulation of the tongue. Similar devices are currently being used by the blind to "see" their surroundings.

Lectures 7 and 8: Building Herself a Better Brain (Neural Development), Doidge Chapter 2

Goal: Chapter 2 of *The Brain that Changes Itself* describes recent findings regarding how repetitive training can help improve cognitive deficiencies. This chapter is a case study in which an individual, while scoring as brilliant in some activities, exhibited deficits in other basic skills (e.g. handwriting) that had her labeled as "retarded." This chapter will serve to describe the role of the cerebral cortex, competition between developing neuronal connections and Hebb's hypothesis of cellular learning as a function of repetitive excitation. Modern hypotheses promote the idea that the size and complexity of cortical territory is of the upmost importance in various cognitive functions but that areas assigned to one task may be reassigned to another; either by accident following tissue damage, or purposefully through specific training exercises.

Relationship to Technology and Its Impact on Society: Technology is mistakenly thought of as exclusively involving engineering and machines. In this section an emphasis is placed on how our behavioral experiences can actually alter the physical structure and consequently the functioning of our brains. Thus, different types of behavioral therapies can be construed as technological approaches to inducing brain plasticity in a way that can have therapeutic benefits.

Lectures 9 and 10: Redesigning the Brain (Plasticity, Cortical Mapping and Learning and Memory), Doidge Chapter 3

Goal: This next chapter introduces the reader to the classical studies in which development of the visual cortex was determined to be dependent upon synaptic activity that originates in the retina. It reinforces Hebb's notion of "cells that fire together, wire together." But in addition, it describes how cortical structure is under constant change due to the strength and timing of electrical activity. No better example is that of learning and memory, which is specifically dependent on the strengthening of old synapses and the formation of new ones. This chapter will serve to discuss our understanding of cortical maps, neuroplasticity, and our understanding of learning and memory, including discussion of the most famous neuroscience case study, that of (the recently deceased) patient H.M., who had a bilateral resection of portions of his temporal lobe containing his hippocampi and resulting in profound anterograde amnesia.

Relationship to Technology and its Impact on Society: Understanding that neural plasticity is an ever ongoing process provides unique insight into how our brains learn and how we can improve ourselves. This process of neuronal plasticity is essential in various paradigms designed to improve neural function. One example is the use of the cochlea implant, a process by which the auditory nerves are directly stimulated because of damage to hair cells. With training, our auditory nerves can interpret signals generated by the electrical device. In addition, using

simple repetitive tasks, we can train our brains to better perform. This concept provided the genesis of various training programs meant to improve the academic performance of children with disabilities as well as improve cognitive function of the elderly.

Lectures 11 and 12: Disorders of the Aging Brain, No Readings

Goal: As medical advancements have increased our lifespan and quality of life, new medical challenges have appeared. From the perspective of the brain, diseases associated with aging have a common feature of cell death in a defined set of neurons. The sad reality is that we will all face these diseases ourselves or through affected family members. This section will focus on Parkinson's Disease and Alzheimer's Disease as two of the most prominent disorders of the aging brain.

Relationship to Technology and its Impact on Society: Like many diseases of the nervous system, sophisticated imaging techniques are used to diagnose disorders of the aging brain. The uses of these imaging tools, along with common drug therapies will be discussed. Further, new technologies such as focal radiation ('gamma knife') and deep brain stimulation will be discussed as means to improve the daily lives of people suffering from these diseases.

Lectures 13 and 14: Midnight Resurrections (Recovery from Brain Injury), Doidge Chapter 5

Goal: Until a few years ago, dogma stated that the central nervous system did not recover from injury. The best example of this school of thought could be observed by following the treatment of patients after a stroke. It was believed that recovery of function was impossible a few weeks following the neurological insult. Again, we now know this is not the case. Through dedicated repetition, neuronal pathways in the brain can be re-routed, allowing an area of the brain initially responsible for one behavior to take on another. This chapter, describing the remarkable recovery of a stroke patient with significant brain loss, will serve to guide students through the hurdles of recovery of function, modern day technologies for repeated measuring of brain structure and function, and new strategies for helping patients recover from central nervous system disruptions.

Relationship to Technology and Its Impact on Society: Key to recovery from stroke is the identification of the type and localization of damage. In this regard the importance of brain imaging is emphasized as well as using imaging techniques to evaluate the progression of recovery.

Lectures 15 and 16: Brain Lock Unlocked (Obsessive/Compulsive and Similar Neurological Disorders), Doidge Chapter 6

Goal: Obsessive/Compulsive Disorder, anxieties and other behaviors that trigger worry are currently believed to be due to the increased excitability of brain regions involved in error detection and drive improper cognitive thoughts or behavioral responses though connections to the cerebral cortex, limbic system and basal ganglia. This chapter will serve to introduce students to brain regions critical in fear response and important for motor control, and how hyperactivity in these regions may adversely affect behavior. More important, modern treatments for phobias and other similar disorders may be counterproductive to the amelioration of a patient's

symptoms. Through the dissociation of improperly paired stimuli, patients can "unwire" their brains to markedly alleviate their symptoms.

Relationship to Technology and Its Impact on Society: Brain imaging is used to illustrate what has gone wrong in the brains of people with obsessive/compulsive disorder, as well as to track therapeutic recovery. A percentage of people with intractable obsessive/compulsive disorder are currently being treated with either small lesions or by deep brain stimulation. The logic and basis for these treatments is discussed.

Lectures 17 and 18: Pain, Doidge Chapter 7

Goal: Most people think of pain as a negative aspect of nervous system function. Yet it is essential for the protection of our bodies. It is a powerful stimulus to let us know of tissue damage and motivates us to alter our behavior to prevent further damage. In rare examples in which pain processing is absent, individuals have experienced horrific burns not knowing their hand was on a hot stove, and in fact, induce self-mutilation without even being aware of their behavior. This chapter will serve to describe the importance of the pain sensory system. And while pain processing is essential to our well being, it is not without its problems. Plasticity in the pain sensory system is responsible for various aversive phenomena, including phantom limb pain and hyper-sensitivity to non-painful stimuli.

Relationship to Technology and its Impact on Society: Over 80 billion dollars a year are spent or are lost in productivity as 50% of the adult population in America suffers from some form of chronic pain. Students learn of the diverse categories of drugs that are used to "control" pain and how they impact different components of our nervous system. In addition, understanding how our brains process sensory information profoundly impacts our perception of pain. No better example of this is some of the newly developed treatments for phantom limb pain. Students learn the origin of phantom limb pain, and how a simple apparatus can rewire the brain to process sensory information correctly to alleviate this pain.

Lectures 19 and 20: Imagination, Doidge Text Chapter 8

Goal: How does the brain recognize self? How does one determine the world around them? The brain of an individual is completely dependent upon sensory information from touch, taste, vision, olfaction and auditory/vestibular cues to determine what is going on around their environment. But the electrical signals coming from our sensory systems need to be analyzed and deciphered by our brains to generate a sense of self. Amazingly, our brain's perception of ourselves is not hard wired. Through very simple stimulation techniques, experimenters can incorporate additional objects into our "self" that when poked or prodded provide the perception that we are being touched, or even generate a sensation of pain. In a reversal of this phenomenon, our imaginations can alter our abilities. For example, recent studies have determined that practicing a dance move does not require actual movement. Individuals just imaging their performance of a dance movement improved to a similar extent as those that actually practiced in a traditional sense. Understanding how we see ourselves as a part of the world and how our thoughts can shape our abilities begins to provide insight into ourselves and our reality.

Relationship to Technology and Its Impact on Society: In this section we discuss the concept of consciousness and apply different imaging technologies to understand what have been

described by philosophers as the 'easy' and 'hard' questions of consciousness. Introduced here is transcranial magnetic stimulation which is a non-invasive way to alter neuronal functioning in awake individuals. An amazing (and perhaps frightening) application of this technology is the use of these magnetic fields to alter the judgment of people in a way that makes them 'morally indifferent'.

Lectures 21 and 22: Addiction, No Readings

Goal: Addictions are an emerging disorder in our society that has a devastating effect on the afflicted individuals and their immediate family members. Addictions are not limited to drugs, but also surface in conjunction with certain foods, shopping, gambling and the like. We are beginning to learn that addictions (regardless of their source) arise from abnormal plastic changes in certain brain regions. Whereas we mostly think of plasticity in the brain as facilitating its repair and therefore beneficial, certain patterns of plasticity can also impair brain function.

Relationship to Technology and Its Impact on Society: Technological advances have allowed us to image the 'addicted brain'. These technologies have both revealed what has gone wrong with the brain during addiction as well as providing insight into why it is so difficult to correct these underlying changes in the brain to effect a cure.

Lectures 23 and 24: Rejuvenation (Stem Cells, Nervous System Maintenance and Recovery), Doidge Chapter 10

Goal: Probably the most widely discussed topic by the general public, yet still poorly understood, is use of stem cells. Stem cells are often described as the future cures to various neurological diseases (e.g. Parkinson's Disease) or the means by which to repair our nervous system (e.g. Spinal Cord injury). This chapter describes the discovery of neuronal stem cells, their presumed role in normal brain function throughout the lifespan of the organism and provides insight into some of the first discoveries of cognitive improvement due to stem cell function. Students will be taught about various forms of stem cells, differences between the different classifications of pluripotent progenitor cells, potential therapeutic roles of stem cells and the significant hurdles that remain before they are widely used for restorative or curative purposes.

Relationship to Technology and its Impact on Society: The development and use of stem cells is probably the most debated area of science today. Understanding what stem cells are, where they can be obtained, how they are processed and how they can be utilized is of the upmost importance for individuals to make informed decisions of their potential health benefit, inherent risks, and alternative treatments.